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URBAN AND INDUSTRIAL DECONCENTRATION IN DEVELOPING
ECONOMIES: AN ANALYTICAL FRAMEWORK

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URBAN AND INDUSTRIAL DECONCENTRATION IN DEVELOPING ECONOMIES:
AN ANALYTICAL FRAMEWORK

John R. Harris*

Historically, industrial development has been associated with increased concentration of population in urban areas. The present-day developing economies of Africa, Latin America, and Asia are proving to be no exception to this trend. Furthermore, there appears to be a tendency for such growth to concentrate on a very few "primate" urban centers, most frequently capital cities, which grow relatively to the smaller urban centers.

This process is giving rise to considerable apprehension on the part of many political leaders for several reasons. First, growing numbers of unemployed migrants in the major cities pose a considerable threat to political stability. Secondly, these economies have insufficient resources to provide adequate water, sewerage, housing, streets, transportation, schools, police and fire protection for burgeoning urban populations. The result is rapid deterioration of the quality of urban services accompanied by mushrooming squatter settlements. Finally, there is growing clamor from representatives of outlying areas that most of the benefits of economic development, particularly the availability of regular jobs in the "modern sector," are being channeled to the major cities and their immediate hinterlands.

Both developing and industrialized countries have attempted to ameliorate this problem to some extent by articulating policies designed

to divert new industry away from the primate centers and towards a number of smaller towns.¹ Frequently some measure of regional equalization of industrial employment has been stated to be a goal for the economy. However, there has been relatively little systematic investigation of the costs and benefits of such policies. Furthermore, little is known about the specific measures required to effect the preferred geographical configuration of industrial growth.

I. An Approach to the Problem

It is of course extremely difficult, if not impossible, to try to quantify the political, social or ethical benefits of a particular policy. However, it may be possible to ascertain the economic costs or benefits to the society of a policy so that decision makers have at least some rough idea of the situation. Specifically, it is useful to ask the question: what will industrial deconcentration cost the economy in terms of domestic (National) product? If the answer turns out to be a negative quantity (economic gains) all is well since economic and political goals will be mutually supporting. However, if the costs turn out to be high, then the decision makers will be forced to decide how they will resolve the conflict between political and economic goals.

Therefore an analytical framework is needed that will enable one to estimate the costs of alternative policies.

It would seem that the place to start is to identify factors that will cause social costs to vary between one or another spatial structure of industry. However, defining a spatial structure in a way that leads to manageable problems is not at all obvious. One way is to consider an

economy as consisting of a limited number of points, each of which is an existing urban center or potential center located in a region of the country. An implicit assumption is that all industrial activity is concentrated in a single urban centre in each region which, while hardly innocent, appears to be a reasonable starting point for analysis.

Factors that will vary among spatial structures can be divided into the following four categories: transportation, labor, direct production costs other than labor, and urban infrastructure and services. The object of the exercise will then be to determine levels of social costs required to produce a given bill of goods when different constraints on spatial structure of industrial activity are imposed. It should be noted that this approach is essentially static. Comparisons will be made between alternative configurations potentially feasible at a single point in time. (At a later point I will briefly discuss making the model explicitly dynamic but this seems to be a reasonable point to begin considering the problem.)

An analytical technique that appears to be suitable for the task at hand is that of mixed-integer programming. In the next section a proposed multi-region programming model will be outlined and the problems of implementing the model will be discussed subsequently.

II. The Model

The first problems to be faced in developing such a model is the choice of an objective function. Although in many ways the most analytically satisfactory approach, which has been followed by Lefebvre [6] and Vietorisz [10], is maximizing output subject to resource availabilities, this is hardly feasible when one is concerned only with a subsector of the economy such as the relatively small industrial sector of most developing economies. Therefore the objective in this model will be to minimize the social costs of producing a predetermined bill of goods with the regional pattern of deliveries also specified. (This approach has also been used by Hurter and Moses [4] and Kendrick [5].) This objective is stated in equation (1).

$$(1) \text{ MIN: } C = \sum_{i=1}^I \sum_{j=1}^J \sum_{k=1}^K \sum_{r=1}^R i^c_r i^{b_{rk}} k_j^X + \sum_{i=1}^I \sum_{j=1}^J \sum_{k=1}^K \sum_{n=1}^N i^p_n i^{M_{nk}} i_j^X + \sum_{i=1}^I \sum_{j=1}^J \sum_{k=1}^K i_j^t i_j^X + \sum_{i=1}^I \sum_{k=1}^K Z_k i^n_k$$

where:

- $i^c_r \equiv$ social cost of a unit of primary factor (resources) r at production point i ($k = 1, \dots, I$; $r = 1, \dots, R$),
- $i^{b_{rk}} \equiv$ input requirement of primary factor r per unit of production of commodity k at production point i ($k = 1, \dots, K$),
- $i_j^X \equiv$ number of units of commodity k shipped from production point i to consumption point j . ($j = 1, \dots, J$),
- $i^p_n \equiv$ social cost of imported or non-industrial intermediate commodity n delivered to production point i . ($n = 1, \dots, N$),
- $i^{M_{nk}} \equiv$ input requirement of imported or non-industrial intermediate commodity n per unit of commodity k produced at point i ,

$ij^t_k \equiv$ social cost of transporting one unit of commodity k from point i to point j . ($ii^t_k = 0$),

$Z_k \equiv$ social cost of having a plant of capacity S_k for producing commodity k , and

$i^n_k \equiv$ an integer variable indicating the number of plants of size S_k for producing commodity k at point i .

The first term on the right hand side of equation (1) is the social costs of primary factors of production used to produce the entire bill of goods. These primary factors will include labor ($r = 1$), power, and water. Capital inputs are not included since I assume that capital costs are independent of location although there is no logical reason why they cannot be included if this assumption is unwarranted. Social costs of labor are not independent of wage policy but can be estimated for alternative wage policies (see Harris and Todaro [3]) and will include not only foregone agricultural output but also specific costs of urban infrastructure that vary directly with population. Other urban infrastructure costs that vary with output will be included in primary resource costs.

The second term in (1) consists of the costs of imported and non-industrial intermediate goods using an appropriate exchange rate and includes transport costs of moving the imports from point of embarkation to using point. Social costs of transporting goods both for intermediate and final uses are contained in the third term of (1). The final term arises from the fact that with economies of scale in some lines of production, excess capacity may have to be maintained. The cost of such capacity, however, should be minimized.

The first of the constraints to be considered is the delivery requirements for final demand of each commodity at each point as shown by

equations (2).

$$(2) \quad \sum_{i=1}^J i_j^X k - \sum_{m=1}^K \sum_{p=1}^J j^{a_{km}} j_p^X m \geq j^B k,$$

$$(j = 1, \dots, J; k = 1, \dots, K),$$

where:

$j^{a_{km}} \equiv$ input requirements of commodity k per unit of commodity m produced at point j , and

$j^B k \equiv$ specified final demand for commodity k at point j .

The first term on the left hand side of (2) is the total availability of k in j while the second term accounts for intermediate uses. The B 's are specified from outside the model. Determination of the B 's actually to be used empirically will be discussed in a later section.

If some primary resources are in limited supply, equations (3) reflect the fact.

$$(3) \quad \sum_{j=1}^J \sum_{k=1}^K i^{b_{rk}} i_j^X k \leq i^R r \quad (i = 1, \dots, I; r = 1, \dots, R),$$

where:

$i^R r \equiv$ total endowment of primary factor r at point i .

These constraints can arise in two ways. First there may be an absolute capacity for providing some resource such as water or the resource may be available only at rising social cost. In the latter case the supply function will be approximated by a series of step functions. This is handled by redefining the primary factor as more than one factor, each of which has its different cost ($i^C r$). For instance, labor may be such a case since

additional labor has to be drawn from further away and may also incur rising marginal infrastructure costs. Then $r = 1$ will refer to the first R units of labor used (i^{R1}) which incur cost (i^C1) and $r = 2$ will refer to the next R units of labor (i^{R2}) which will incur a higher cost (i^C2). Commodities will also have to be redefined. For instance, shoes made with the lower cost labor will be designated $k = 4$ and shoes made with the higher cost labor will be $k = 5$. Then $i^{b15} = 0$ and $i^{b24} = 0$ while $i^{b14} = i^{b25} > 0$. Equations (2) will then have to be modified so that the sum of net availabilities of $k = 4, 5$ will be greater than or equal to the required deliveries of shoes in i . It is immediately apparent that such a procedure should be used only when necessary since the number of variables in the program will be multiplied by the number of steps in the supply function of each primary resource. (Note that with five regions and ten commodities the program already has 250 of the choice variables ij^X_k).

The crucial constraint in the model which allows deliberate action to spread activity in a geographically desirable manner is (4).

$$(4) \quad \sum_{j=1}^J \sum_{k=1}^K i^{b1k} ij^X_k - i^\alpha \left\{ \sum_{i=1}^I \sum_{j=1}^J \sum_{k=1}^K i^{b1k} ij^X_k \right\} \geq 0,$$

$$(i = 1, \dots, I).$$

In equation (4) $r = 1$ is labor which is treated as a single primary factor. (If, because of rising social costs, labor was designated as more than one resource, one would have to sum over the labor categories.) The first term of (4) is total employment generated in i while the term in brackets is total employment created in the entire industrial sector. Therefore (4) states that employment at i will have to be at least some fraction i^α of

total employment and of course $\sum_{i=1}^I i^{\alpha} \leq 1$. I am assuming that the real political objective of deconcentration is spreading employment opportunities more evenly than is presently the case. Other measures of activity that could be regionally constrained include gross output, value added, or wage bill, but in each case additional values would have to be included in the model and it is not clear why the first two would have as much political significance as employment. If wage bill is to enter, all that is required is for each term in (4) to be multiplied by the appropriate wage. A regional balance-of-payments constraint is also a possibility but seems less relevant for this problem than the others mentioned.

The final constraint to be considered is levels of productive capacity in each region for each good. If we are concerned only with production arising from net additions to capacity over some time period, sufficient capacity will have to be provided to produce the desired bill of goods. Since capital costs are probably insensitive to location, it would at first appear that the model described by equations (1) - (4) will dictate the locations at which this new capacity should be located which, indeed, is the essence of the problem I am concerned with. However, if for some goods the production cost differentials are small relative to commodity transportation costs, the logic of the model is such that there will be a strong tendency towards self sufficiency at each point. This arises from the assumption of constant returns to scale implicit in the model. Indeed, if there are constant returns that is exactly what should happen.

If, however, there are economies of scale in some activities it will

become optimal to balance transport costs against production cost savings, and a more concentrated production pattern for any one good will arise. Scale economies present a considerable difficulty since the feasible set becomes non-convex and the ordinary linear programming techniques break down. Manne [7] has dealt with the case of continuous economies of scale in plant size and shows that the problem is manageable but complicated. An alternative approach which appears reasonable is to assume that there is a plant size at which costs are minimized and that variable production costs are constant for any level of production in such a plant. This requires that productive capacity be provided in even multiples of such a plant size according to equations (5).

$$(5) \quad \sum_{j=1}^J i_j X_k - i^n_k S_k \leq 0, \quad (k = 1, \dots, K; i = 1, \dots, I)$$

where

$S_k \equiv$ the optimal plant size for producing commodity k , and
 $i^n_k \equiv$ a variable that is free to take on only integer values.

The inclusion of constraints (5) turns the problem into one of mixed-integer programming. Computational techniques exist for such a problem and have been used by Kendrick [5]. Since computation time is greatly increased by adding the integer constraints it makes sense to first compute the program without (5) and examine the pattern of plant sizes that emerge in the solution. If they are implausibly small, it is then worthwhile to introduce constraints (5). It should be emphasized that these constraints will not apply to all industries but only to those in which economies of scale are important.

The final constraint is the requirement that all X's are non-negative.

$$(6) \quad i_j^X k \geq 0 (\text{all } i, j, k).$$

With this model one can begin to determine the costs of alternative values of the i^{α} 's in (4). First the optimal solution will be computed when (4) are omitted which gives the minimum possible value of (1) for the given pattern of final demands, technological constraints, and factor costs. Then by introducing (4) the cost minimizing solution can be computed with additional social costs incurred by imposing specific constraints on the regional distribution of activity.

It should be noted explicitly how each of the elements of cost that are liable to vary with location are taken account of in the model. Transport costs appear directly in the minimand (1) in the form of t coefficients for moving final and industrial intermediate goods and in the P coefficients for imported and non-industrial inputs. Social costs of labor appear in the c coefficients (i^C_1 is usually taken to be labor although there may well be more than one kind of labor included) and direct production costs are accounted for by the remaining c coefficients and regional differences in the various input coefficients (b 's and M 's). The important elements of urban infrastructure are accounted for in two ways. First, elements of infrastructure cost that vary with population (e.g. housing, sewerage, police, and fire protection, etc.) are included in the i^C_1 's while those that vary with production (e.g. power and water) are included directly as primary factors of production.

It may appear to be a glaring omission that the model as outlined above fails to specify any connection between levels of production (hence

income generated) and consumption. Such a relationship could be added, although the problem would then become non-linear. Computation problems aside, given the relatively small share of income originating in the industrial sector, moderate changes in industrial activity in a region will probably not have a great effect on regional consumption which depends on total regional income. Recall that a goodly portion of value added will accrue to owners of capital assets and there is no reason to require that this income will give rise to consumption or investment in the same region. A reasonably simple way to handle the problem is to vary the B's somewhat when the α 's are varied and observe changes in (1) that result.

The other obvious shortcoming of the model is that it fails to consider the externalities that are usually referred to as agglomeration effects. While it dodges the issue somewhat ingenuously, the argument can be made that deconcentration will mean that some economies of agglomeration are lost; yet, in the long run, this will be more than offset by creating additional centers in which agglomeration economies will be reaped. [10] This, of course, requires that agglomeration economies increase at a decreasing rate with center size. It is notoriously difficult to concretely identify agglomeration economies, and I am not aware of any empirical studies that have effectively quantified them although a recent paper by Nixon [8] reports negative findings on agglomeration economies for Nairobi. Nonetheless, the notion of cumulative causation remains an appealing explanation of regional growth [2] and one has to count it as a weakness in the model that such effects cannot be incorporated.

I have already indicated how the solutions to this model can be used to give a quantitative estimate of the social costs incurred by forcing an

industrial pattern to be less geographically concentrated than it would be in the absence of intervention. The second part of the problem is to devise policies that will cause the desired pattern to become a reality. Again this model can be helpful.

The dual problem, in formal notation, is stated in equations (7) through (9).

$$(7) \quad \text{Max: } M = \sum_{k=1}^K \sum_{j=1}^J [j^V_k] [j^B_k] - \sum_{r=1}^R \sum_{i=1}^I [i^W_r] [i^R_r]$$

subject to:

$$(8) \quad j^V_k - \sum_{m=1}^K [i^{a_{mk}}] [i^V_m] - \sum_{r=1}^R [i^{b_{rk}}] [i^W_r] + [i^{G-\sum_h \alpha_h G}] i^{b_{1k}} - i^{Q_k} \\ \leq i_j^t k + \sum_{r=1}^R [i^{b_{rk}}] [i^C_r] + \sum_{n=1}^N [i^{m_{nk}}] [i^P_n],$$

(j = 1, ..., J; i = 1, ..., I; k = 1, ..., K), and

$$(9) \quad S_k i^{Q_k} \leq Z_k$$

(i = 1, ..., I; k = 1, ..., K),

where

$j^V_k \equiv$ imputed value of good k at point j for both final and intermediate use,

$i^W_r \equiv$ imputed unit value of primary factor r at point i,

$i^G \equiv$ cost to the system of constraining the regional distribution of activity to force employment of one more worker at i, and

$i^{Q_k} \equiv$ imputed unit value of capacity for producing one unit of k at point i,

and the requirement that all V, W, G, and Q variables be non-negative.

The dual variables can be interpreted as imputed values of the final goods and various constraints from the primal problem. The i^G variables are particularly interesting because they reflect the additional social cost incurred by forcing one more unit of labor to be hired at point i .

It is interesting to examine the fourth term in (8) in some detail. $\sum_h h^\alpha h^G$ is a weighted sum of the G 's and can be interpreted as an average value of G . If $\sum_i i^\alpha = 1$ then all of the constraints (4) will be satisfied as equalities and the G 's will be positive. If all these G 's were positive and equal, then the above term will be equal to zero. On the other hand, if $\sum_i i^\alpha < 1$, then some of the constraints (4) will be satisfied as inequalities and the corresponding G 's will = 0. The above term in the dual constraint for such regions will be negative (as it will be also for any regions for which the G variables is less than the average). A negative value for the term can be interpreted as an imputed quasi-rent per unit of labor used in the region. If the term is positive, as it will be in regions with higher than average G 's, it can be considered as a negative quasi-rent per unit labor used. If a tax equal to $[\sum_h h^\alpha h^G - i^G] i^b k$ were levied on each unit of commodity k produced in i (a subsidy if the above term is negative) producers would be compensated for locating in the relatively high cost areas where additional employment is desired for political or social purposes. However, in determining tax and subsidy arrangements attention must also be paid to the accrual of quasi-rents on capacities as well as divergences between social and private costs.

There remain two outstanding issues with respect to policies. First, it is quite clear that private costs are not identical to social costs in many cases. Minimum wage legislation makes labor considerably more

expensive than its opportunity cost, it is not clear that private and social costs of power are identical, and it is quite certain that transportation charges and social costs diverge substantially. Therefore an examination of the entire price structure is required before specific tax and subsidy proposals can be outlined. It may be useful to note, however, that if private and social costs diverge uniformly at all locations, the divergence becomes unimportant for the location problem although other inefficiencies in resource allocation will occur. The other issue is fundamental. The logic of the linear programming model implies perfectly competitive behavior on the part of producers or a centrally planned economy adhering to Lange-Lerner Rules. Much of the analysis is still relevant to non-competitive firms providing that they are cost minimizers. The problem arises in a severe form, however, if entrepreneurs make location decisions according to personal locational preferences as well as cost factors. It is frequently alleged that expatriate investors locate firms in capital cities because of the congenial living conditions and amenities even though other locations may be more profitable. Such preferences will either have to be taken into account in determining tax and subsidy schemes or else some form of direct control through licensing or land allocation must be resorted to. It is important, however, to consider the incentive effects of such policies since they could lead to less investment and underfulfillment of aggregate production targets.

III. Implementation

While the quantity of data required for implementation of the model is far from trivial, I have been able to collect the requisite data primarily from existing sources in Kenya. The situation should be fairly similar in most other developing countries.

For Kenya it has proved convenient to treat the economy as consisting of five points and to include ten industrial sectors. The national five-year plan provides output targets for each of these industrial sectors in 1974 and allocation of this final demand between cities can be made on the basis of regional income estimates. Industrial exports are assigned as final demand to the city which serves as port of departure.

Input coefficients of imports, primary factors, and intermediate industrial goods are being made available from the input-output table which is presently being prepared for the economy. Transport coefficients, to which the model is likely to be extremely sensitive, are available from a recent study of the East African transport system which attempted to estimate variable costs of transporting specific commodities between each node in the region. Social costs of labor at each city will be estimated from a current study of rural-urban migration, while cost data pertaining to urban infrastructure is quite fragmentary and Indian data may have to be used in a modified fashion.

The foregoing suggests that data requirements should not prove to be an insuperable obstacle to the use of the programming model as a practical tool for evaluating policy. However, the data vary substantially in quality and it is imperative that sensitivity analysis be performed to determine

where additional resources should be devoted to refining data. Standard mixed-integer computer programs are now available to handle problems of this size.

IV. Desirable Extensions and Modifications

The approach discussed so far is clearly only a first step. One of the obvious ways in which it could be improved would be to make the model explicitly dynamic. If this were done, one could derive optimal time paths of investment in both productive capacity and infrastructure at each location. Such an approach is feasible, as has been shown by Kendrick [4], but must be taken as a second stage of analysis since additional data on capital and infrastructure requirements would be needed.

Secondly, the model can easily be extended to incorporate points in more than one country and could be quite useful in determining rational locational patterns of industry within a common market or larger regional grouping of countries. It is interesting to note that a rather similar approach is being taken in a study by the Economic Commission for Africa that will attempt to determine appropriate patterns of industrial location and specialization for Eastern Africa. In this exercise a regional balance-of-payments constraint is probably the most reasonable one (rather than employment or value added) since the problem of financing multilateral trade in industrial goods is important.

Thirdly, it would be nice to include the agricultural and other non-industrial sectors and maximize output subject to resource availabilities and regional activity level constraints. It makes sense to be concerned with relative levels of total income among the regions rather than with industrial employment only. However, this becomes an extremely complicated project and indeed would involve a complete planning model with regional detail. Data requirements would become extremely onerous and the computational problems would also become formidable. This remains a desirable

but still far-off extension of the basic approach outlined here.

Finally, it would be desirable to relax the assumption of regional industrial activity being concentrated at a single point even though the assumption is consistent with the notion that industry should be concentrated in a limited number of growth centers so as to reap the benefits of economies of scale and agglomeration. However, we still know relatively little about, and the conceptual tools are still primitive for looking at, the optimal dispersion of activity among various sized centers within a region. At the moment I am unable to do more than suggest that this is an issue of fundamental importance which deserves attention.

VI. Conclusion

This paper presents an analytical approach to evaluating the costs that would be incurred from forcing industrial and urban growth into a less concentrated pattern than has been emerging spontaneously in many developing countries. A multi-region programming model incorporating both rising supply functions and integer constraints on plant size has been outlined. Finally, some desirable extensions to the model have been discussed.

While there are serious limitations to such an approach, it would seem to be a useful first step towards providing a quantitative basis for guiding policy decisions in this very important area of concern.

NOTES

- * Assistant Professor of Economics, Massachusetts Institute of Technology. I am grateful to the Rockefeller Foundation for financial support and to Peter Diamond for useful criticisms on an earlier version of this paper which was presented to the University of East Africa Social Science Conference at Kampala in December 1968. However, I alone am responsible for remaining errors.
1. Some information regarding approaches that have been tried can be found in [9]. Particularly, the English, Indian, French, and Yugoslav experiences are of interest.

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